

## Radiology Corner Case #15

### Subtle Lisfranc Injury: Low Energy Midfoot Sprain

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#### History

A year prior to the current presentation, the patient, a 19-year-old Marine, reported injuring his right foot while landing from a jump. Initially the man complained of pain along the dorsum of both feet in the region of the first metatarsophalangeal joints. However, over the intervening year, the pain was persistent and increased in the dorsal right foot, noticeably after running. His initial imaging evaluation included radiographs obtained with weight bearing in the anterior-posterior (AP, Figures 1A and 1B) and lateral plane (Figure 1C), and technetium 99m bone scan (Figure 1D).

#### Diagnosis

##### Low-Energy Midfoot (Lisfranc) Sprain

#### Imaging Findings

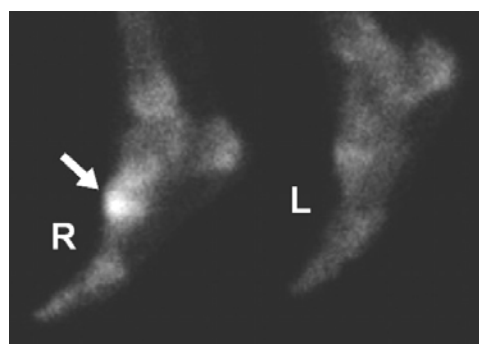
The weight-bearing AP (Figure 1A) revealed a small irregular bony fragment in the region of the Lisfranc ligament between the medial cuneiform and the lateral aspect of the base of the second metatarsal, that was best seen by magnification of the image (Figure 1B, arrow). In addition, the AP radiograph shows a 2 mm incongruity of the alignment of the medial aspect of the second metatarsal with the medial aspect of the middle cuneiform (Figure 1B, dotted lines). The lateral weight-bearing radiograph (Figure 1C) did not show compromise of the arch height or dorsal subluxation of the tarsometatarsal joint. The technetium bone scan (Figure 1D) shows focal increased radionuclide tracer uptake (arrow) over the proximal first and second metatarsals of the medial aspect of the right foot. Computed Tomography (CT) was also performed and confirmed the findings seen on plain radiographs. On CT, both the 2 mm lateral displacement of the second metatarsal and the bone fleck (Figure 1E, oblique axial reconstruction, arrow) in the region of the Lisfranc ligament were noted. A second additional avulsion fracture (Figure 1F, arrowhead) was noted adjacent to the plantar aspect of the base of the second metatarsal.



**Figures 1A and 1B.** Weight-bearing AP radiograph (1A, standard view; 1B, magnified view) of the right foot. The AP view demonstrates widening of the Lisfranc joint with a 3 mm diastasis between the medial cuneiform and base of the second metatarsal, and a 2 mm diastasis between the first and second metatarsals. The magnification of the weight bearing AP radiograph (1B) more clearly shows the 2 mm incongruity or “off step” of a line connecting the medial aspect of the proximal second metatarsal with the medial aspect of the middle cuneiform. There is also suggestion of a bony fragment in the region of the Lisfranc ligament (black arrow), the “fleck sign.”



**Figure 1C.** Weight-bearing lateral radiograph of the right foot demonstrates no signs of decreased arch height (double-sided arrow between black lines; compare with Figure 6).



**Figure 1D.** Bone scan of both feet with medial right foot (R) and lateral left foot (L) against the nuclear medicine camera demonstrates a focal area of increased radiotracer uptake in the right midfoot (arrow).

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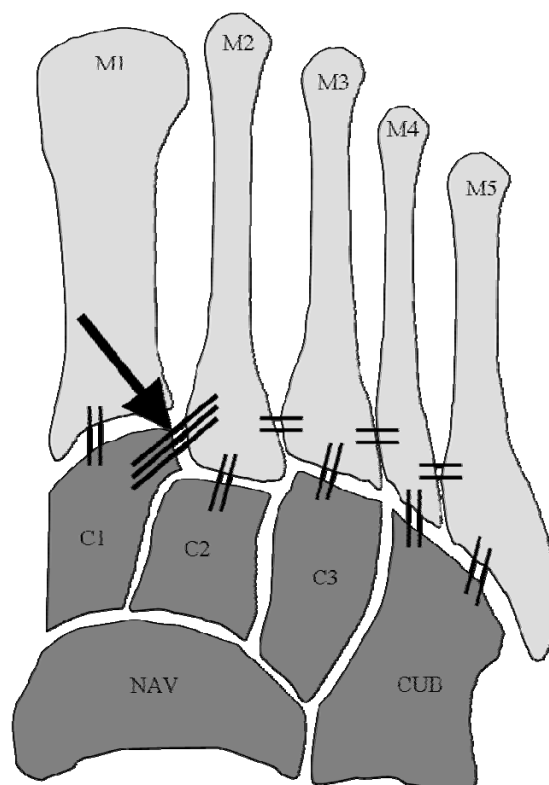
**Figures 1E and 1F.** Reconstructed oblique axial image (Figure 1E) from a CT of the right foot confirmed both the small bony fleck in the region of the Lisfranc ligament (white arrow) as well as incongruity of the imaginary medial line between the second metatarsal and middle cuneiform. Coronal reconstruction (Figure 1F) demonstrated a small bony fleck in the region of the Lisfranc ligament (white arrow) as well as an additional bone fragment adjacent to the plantar surface of the base of the second metatarsal (white arrowhead).

### Discussion

The tarsometatarsal articulation, also called the Lisfranc joint, is a bone and ligament complex that provides stability to the relatively rigid midfoot and the transverse arch of the foot.<sup>1</sup> The incidence of Lisfranc injury or sprain is rare in the general population, occurring approximately once per 60,000 persons per year.<sup>2</sup> But the incidence of indirect Lisfranc injury, ranging from partial ligamentous tear without displacement to complete tears with frank diastasis, is higher in athletes. Meyer et al.<sup>3</sup> reported an incidence of Lisfranc sprain in up to 4% per year among college football players, second only to turf toe in foot injury incidence. Lisfranc sprains in the athlete may be initially overlooked because the findings may be subtle or unappreciable on traditional radiographs.<sup>4</sup> Delayed diagnosis may lead to long-term disability and pain or deformity due to a loss of arch height.<sup>5</sup> Given the high level of athletic and other similarly physically stressful activities undertaken by service members, proper recognition of subtle Lisfranc sprains is particularly important for military health care providers.

The Lisfranc ligament is a strong stabilizing ligament coursing from the lateral aspect of the medial cuneiform to the medial plantar surface of the base of the second metatarsal (Figure 2, arrow). It is an important stabilizer of the midfoot, helping to keep the recessed second metatarsal base firmly placed at the apex of the transverse arch of the foot – the keystone of the arch.<sup>3</sup> It is also the only connection of the lesser metatarsals (II-V) to the first ray because proximal intermetatarsal ligaments exist between each of the lesser metatarsals but not between the first and second metatarsals (Figure 2).<sup>6,7</sup> Secondary soft tissue stabilizers of the Lisfranc joint include the plantar fascia, the foot intrinsic muscles and tendons, and the insertions of the anterior tibialis, the posterior tibialis, and the peroneus longus tendons.<sup>1,3</sup>

Many cases of Lisfranc ligament injury, particularly those that occur due to high-energy trauma, result in fracture-dislocation with deformity that is obvious clinically and radiographically. Establishing the correct diagnosis for a



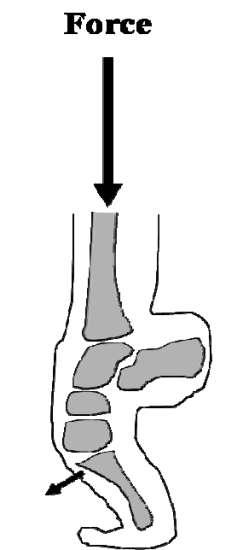
**Figure 2.** Diagram illustrating the stabilizing ligaments of the Lisfranc joint. The Lisfranc ligament (black arrow) runs from the lateral aspect of the medial cuneiform (C1) to the plantar medial aspect of the base of the second metatarsal (M2). The intermetatarsal ligaments connect the lesser metatarsals to each other, but none exists between the first and second metatarsals. [M1 through M5 = metatarsal 1 through 5; C1 = medial cuneiform; C2 = middle cuneiform; C3 = lateral cuneiform; CUB = cuboid; NAV = navicular]

subtle Lisfranc injury, like those encountered with athletic activity, may be difficult even after obtaining a good history, physical exam, and initial radiographs. Lisfranc sprains in the athlete typically occur with an indirect low-velocity force, with most athletes describing a longitudinally directed axial force sustained when the foot is in a plantar flexed and slightly rotated position (Figure 3).<sup>8</sup> Other less common low-velocity mechanisms of injury to the Lisfranc joint include forced forefoot abduction, crush injuries, and non-specific twisting or falling injuries.<sup>4</sup> Physical exam findings include variable swelling, point tenderness between the first and second metatarsal bases, asymmetry in the amount of space between the first and second toes, ecchymosis around the plantar aspect of the joint, and pain with provocative tests such as axial midfoot compression, first to second metatarsal superior/inferior shear, forefoot abduction on a stabilized hindfoot with or without pronation, and first to second metatarsal abduction.<sup>6-9</sup> Weight-bearing ability is inconsistent as a clinical sign of injury severity, with many patients being able to both bear weight acutely and to retain a surprising level of functional mobility.<sup>3,10</sup>

Initial radiographic signs of Lisfranc injury on standard non-weight-bearing AP, lateral, and 30 degree internal oblique radiographs include diastasis (> 2 mm distance as measured on unilateral views, or > 1 mm side-to-side difference) between metatarsal bases (particularly the between the first and

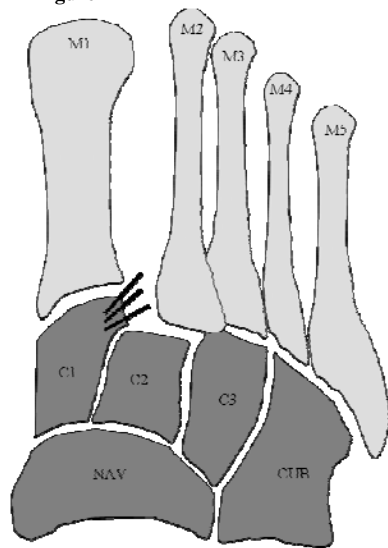
second), between the medial cuneiform and the base of the second metatarsal, between cuneiforms, or anywhere along the tarsometatarsal joint (Figure 4).<sup>4</sup>

Figure 3



**Figure 3.** Illustration of the typical indirect mechanism of injury to the Lisfranc joint sustained during athletics, typically an axial load on a plantar flexed foot. Not shown is the rotational force that often accompanies the axial force during injury to the Lisfranc joint.

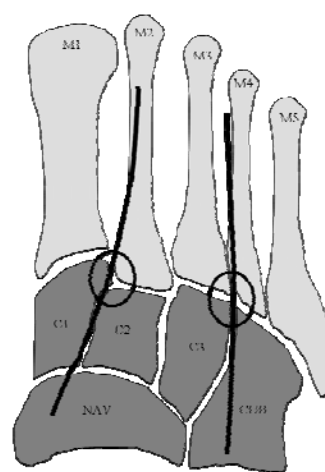
Figure 4



**Figure 4.** Diagram illustrating the characteristics for a midfoot sprain of the first to second intermetatarsal with diastasis between the medial cuneiform and the second metatarsal that results from injury to the Lisfranc ligament.

Another approach to identifying abnormalities of the Lisfranc joint is to carefully assess the alignment of each metatarsal with its corresponding tarsal bone.<sup>11</sup> Foster and Foster<sup>12</sup> reviewed standard non-weight-bearing radiographs for 200 normal individuals and 6 patients with Lisfranc fracture-dislocation. They determined that the most consistent, and therefore, most reliable measure of tarsometatarsal joint congruency was alignment of the medial aspect of the second metatarsal with the medial aspect of the middle cuneiform, as seen on both AP and 30 degree internal oblique views (Figure 5). Norfray et al.<sup>11</sup> agreed with this finding but further stated that offsets should never occur between any of the first three metatarsals with their corresponding tarsal bones. Furthermore, they described the importance of gauging the congruency of the lateral tarsometatarsal joints by checking the alignment of the lateral border of the third metatarsal with the lateral border of the lateral cuneiform, best seen on the 30 degree internal oblique (Figure 5). Offset or discontinuity of either of these imaginary lines should strongly suggest a Lisfranc injury.

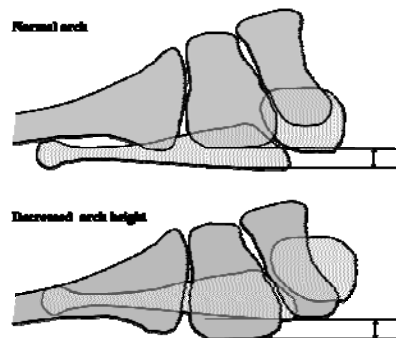
Myerson et al.<sup>9</sup> state that the primary clue to identifying Lisfranc injury is what they term the "fleck sign," which is the presence of a small bony fragment between the base of the second metatarsal and the medial cuneiform. This fleck of bone represents a small avulsion fracture of either the proximal or distal attachment of the Lisfranc ligament and was present in 90% of patients with Lisfranc fracture-dislocation injuries.



lateral third tarsometatarsal joint spaces (circles) suggests disruption of the Lisfranc ligament.

**Figure 5.** Diagram illustrating the two imaginary lines as seen on AP and oblique radiographs which when congruent suggest the Lisfranc joint to be intact. The medial line runs from the medial aspect of the base of the second metatarsal to the medial aspect of the middle cuneiform. This relationship is the most consistent and reliable tarsometatarsal relationship seen in normal individuals.<sup>12</sup> The lateral line, best seen on 30 degree internal oblique but which can also usually be seen on AP, runs from the lateral aspect of the third metatarsal to the lateral aspect of the lateral cuneiform.<sup>11</sup> Disruption of either imaginary lines, namely at the medial second or

Radiographic signs of Lisfranc injury may be subtle or not apparent, and may initially be read as normal in up to 20-50% of cases, with diastasis indicating Lisfranc ligament injury only being identified later.<sup>13-15</sup> Vuori et al.<sup>15</sup>, however, assert that despite the poor sensitivity of early non-weight-bearing radiographs in published literature, careful inspection of the initial non-weight-bearing AP and oblique views should yield the appropriate diagnosis in most cases.<sup>11,12</sup> Other investigators have stressed the importance of full-weight-bearing AP and lateral views in demonstrating radiographic signs of Lisfranc ligament injury, particularly first to second metatarsal diastasis, best seen on the AP, and reduced longitudinal arch height, best seen on the lateral view by comparison of the distance between the inferior aspect of the base of the fifth metatarsal to the inferior aspect of the medial cuneiform (Figure 6).<sup>5,10,13</sup> Oftentimes weight-bearing views are not possible due to pain, so some investigators instead recommend various non-weight-bearing oblique or stress views.<sup>8,9</sup> The proponents of weight-bearing views counter that manual stress and oblique views have not been standardized and may not be adequate, and that pain free weight-bearing views may be obtained with an adequate anesthetic ankle block.<sup>5,13</sup>



**Figure 6.** Illustration of the landmarks used to determine decreased arch height due to Lisfranc injury using the weight bearing lateral view. The distance from the inferior aspect of the base of the fifth metatarsal to the inferior aspect of the medial cuneiform is measured and compared to the contralateral side. In normal individuals the inferior aspect of the medial cuneiform is always

superior to that of the base of the fifth metatarsal. In individuals who have suffered Lisfranc ligament disruption with a resulting decrease in arch height, the distance is decreased or the relationship may even be reversed, as is illustrated.

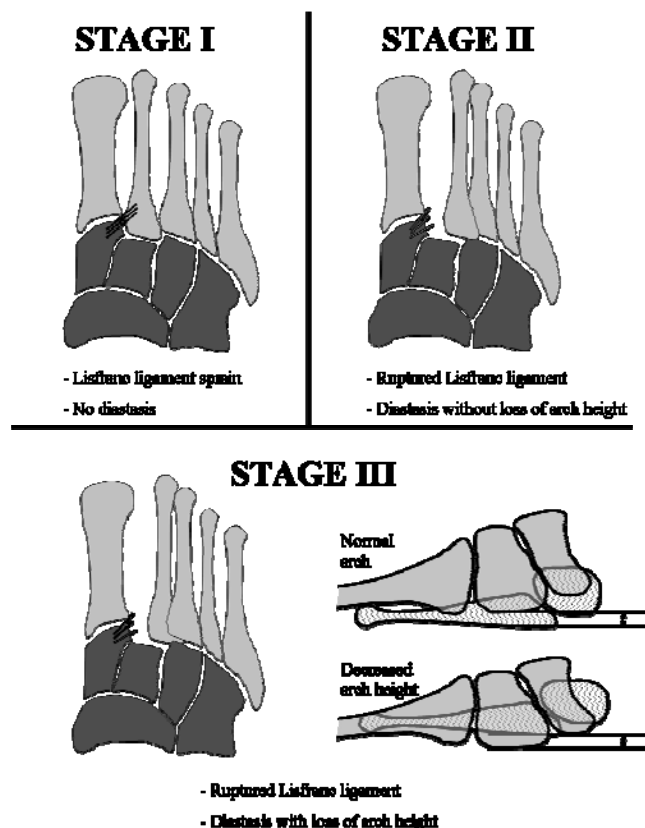
Additional diagnostic modalities used in an attempt to better demonstrate subtle Lisfranc injuries include bone scan,

magnetic resonance (MR), and CT. Of these, bone scan and MR seem to show the best clinical utility, although CT also has several advantages including rapid application without special positioning, excellent demonstration of tarsal and metatarsal fracture or displacement, and the ability to identify any subtle fractures.<sup>16</sup> Bone scan has the advantage of high sensitivity and wide availability at a relatively low cost.<sup>13</sup> Its disadvantages include poor anatomic resolution, whole body radiation exposure, and low specificity. Nunley et al.<sup>13</sup> used bone scan to further classify any patient with a suspected Lisfranc sprain who failed to demonstrate first to second metatarsal diastasis on weight-bearing radiographs. They reported 100% sensitivity and near-optimal clinical outcomes in their small retrospective series. Several authors have demonstrated the utility of MR in visualizing and characterizing Lisfranc ligament normal anatomy and injuries.<sup>4,6,17</sup> Potter et al.<sup>4</sup> used MR to help guide clinical decision making in subtle Lisfranc injuries. In 23 patients with a history of midfoot trauma primarily due to athletic injury who presented with subtle diastasis between the first and second metatarsals, they found that MR was able to differentiate partial, near complete, and complete Lisfranc ligament tears from the normal Lisfranc ligament.

There has been some controversy in the literature regarding appropriate treatment for the typically lower-energy subtle Lisfranc injury. In general, the treatment of Lisfranc fracture-dislocation requires meticulous restoration of normal anatomic alignment by whatever means necessary (i.e. conservative closed reduction or more aggressive open reduction with internal fixation).<sup>2,9,15</sup> In less dramatic Lisfranc sprain as seen in athletes, Meyer et al.<sup>3</sup> and Shapiro et al.<sup>7</sup> have shown non-operative treatment to be sufficient even when diastasis is present. Nunley et al.<sup>13</sup> point out, however, that there were only three athletes out of 23 in the series of Meyer et al.<sup>3</sup> who had a diastasis at the first to second metatarsal, and one of these suffered recurring midfoot pain with high-demand activity. In the other study by Shapiro et al.<sup>7</sup> the correlation between mild diastasis and outcome was not shown. Eight of the athletes in their series with a 2-5 mm first to second metatarsal diastasis were treated with immobilization only and had excellent outcomes with an average full pain free return to sports at 3 months. These findings are in direct contrast to those of Curtis et al.<sup>8</sup>, who concluded from their series of 19 patients that anatomic reduction, most reliably performed with open reduction and internal fixation, of the Lisfranc joint was essential if long-term pain, disability, and deformity were to be avoided.

Several classification schemes have been developed in an effort to identify Lisfranc injury patterns and to help guide treatment. While a review of these schemes is beyond the scope of this paper, the classification scheme proposed by Nunley et al.<sup>13</sup> for Lisfranc sprain in athletes provides a clear and relatively simple approach to the classification and treatment of low-energy Lisfranc injury (Figure 7). Nunley et al.<sup>13</sup> developed their approach based on weight-bearing radiographs and bone scans in athletes with Lisfranc sprains, emphasizing the need for internal fixation (closed reduction if possible; open reduction if needed) to restore full anatomic

alignment in any patient with a greater than 1 mm difference of the first to second metatarsal distance on comparison views. Although their sample size was small (n=15), their results were impressive (excellent outcome in 93 %) despite the fact that eight of the fifteen athletes received a late diagnosis, with a greater than 4 months average delay to diagnosis. Based on their experience, they stressed the importance of obtaining adequate weight-bearing radiographs (using an ankle block as needed for pain relief) because diastasis was only evident on weight-bearing radiographs views in 50 percent of patients (i.e. non-weight-bearing radiographs were "normal" in 50 percent).



**Figure 7.** Diagram illustrating Nunley et al.'s classification of midfoot sprains in the athlete.<sup>13</sup> Stage I represents a Lisfranc ligament sprain with no diastasis on weight bearing, no loss of arch height, but an increased uptake on bone scan. Stage II injuries have 1-5 mm of first to second intermetatarsal diastasis due to Lisfranc ligament rupture, but no loss of arch height. Stage III injuries have diastasis and a loss of arch height, as measured as a decrease or inversion of the distance between the plantar aspect of the base of the fifth metatarsal and the plantar aspect of the medial cuneiform as seen on a weight bearing lateral radiograph.

In general, stable minimally to non-displaced Lisfranc sprains are treated with cast immobilization until weight bearing is pain free, typically between 4 to 10 weeks followed by some period of graduated return to full-weight-bearing status. Unstable injuries, by stress views or by diastasis criteria, require anatomic reduction either by closed percutaneous reduction with internal fixation or open reduction with internal fixation followed by a variable period of protection with casting, restricted weight-bearing, and eventual hardware removal.<sup>3,8,10,13</sup>

While low-energy Lisfranc injuries may seem relatively unimpressive clinically and radiographically, they can have a large and lengthy impact on function, particularly for those in physically demanding vocations and avocations, such as in the military. Maintaining a high index of suspicion for Lisfranc sprain, being aware of the subtle radiographic signs, and understanding what constitutes an adequate radiographic workup will help military health care providers to identify this often overlooked foot injury early on so that appropriate management can be instituted to avoid disability.

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